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NEW ENTREPRENEURSHIP TOWARDS BIOECONOMY

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New Entrepreneurship towards Bioeconomy

This thesis was done to study the fundamentals of bioeconomy concept along with the bio-based market and the entrepreneurship venture. In the light of it, the author created a handbook of bioeconomy fundamentals for academic readers as the outcome. The handbook will be a helpful guideline that assists the readers in understanding the concept of bio-based economy, its market, entrepreneurial ventures in bioeconomy as well as its development.

In this thesis, a secondary study on the bioplastics was implemented to understand the reasons behind the recent popularity of bioplastics and support the narration of bioeconomy concept. This secondary study applied a qualitative approach with archival and documentary research method for data collection and data analysis. The reliable data were generalized into research findings. The research findings were made used to answer the main research question in the end.

The secondary study had been successfully conducted, which generated reliable and valid findings due to the critical selection and thorough comparison of many trustworthy data sources from the Internet. The findings were presented in a logical manner that let the author firstly understand those facts with ease and then be able to answer the main question of this secondary study. The result had been clearly delivered at the end of this thesis. The answer to the reason of bioplastics popularity not only explained a segment of bioeconomy but also raised the concern over bioplastics, which might be beneficial to the readers.

The thesis had provided the author himself valuable information from the topic as well as the secondary study. Additionally, the author had learned and improved several skills by writing this thesis and creating the handbook for the outcome. Generally, this whole thesis process had been successfully finished with the expected outcome.

Key words bioeconomy, bio-based economy, entrepreneurship, bioplastics, sustainable development

CONTENTS

1 INTRODUCTION

Human activity since the mid-20th century is the main driver of climate change (Website of NASA 2019). It is mostly because our society is driven by fossil resources. However, fossil resources are unfortunately finite and adversely affect the planet in many forms. Consequently, we cannot compromise our future generations. Plus, the world population never stops growing and our demands continue to increase. Fossil fuel scarcity; world population; climate crisis with other global challenges call for a critical change in our system.

Bioeconomy or bio-based economy makes use of renewable resources to provide our society with foodstuffs, materials, energies, and many more. This is known as a primary step towards sustainable development. The transition from the traditional economy to a bio-based economy is one of the major changes that tackle global challenges by utilizing natural resources, mitigating climate change, and ensure global food security.

The author expects to deliver an informative and helpful bioeconomy handbook as the thesis outcome. Therefore, this thesis is going to introduce the fundamentals of the bio-based economy concept. Along with this concept, the bio-based market will also be examined to find out the range of bio-products and entrepreneurship opportunities. Further in this thesis, the author will address the supporting tools and the roles of government in the bioeconomy transformation; and many of the bioeconomy challenges and opportunities. For the empirical part, secondary research on bioplastics will be integrated so that readers will have a closer look at the potentials of biobased products as well as their potential for future entrepreneurship.

2 THE THESIS PURPOSE AND THE CONCEPTUAL FRAMEWORK

2.1 Purpose of the study

The purpose of this thesis is to mainly study the bioeconomy concept, the market development along with entrepreneurial ventures in the bioeconomy. As the world is facing various challenges such as climate change, food security, resource scarcity, bioeconomy is one of the major solutions to tackle these challenges. Bioeconomy uses bio-based resources instead of fossil fuels, which represents a great move towards a sustainable society. Thus, understanding the fundamentals of bioeconomy, its products as well as market opportunities will be an essential step for the transition to a greener economy.

2.2 Objectives

A handbook of the bioeconomy fundamentals will be the outcome of this thesis. It will cover the bioeconomy concept, bio-market development; transforming tools, and the future of bioeconomy.

To have this handbook complete, there are five main objectives to be done:

1. Identifying the bioeconomy concept
2. Exploring the bioeconomy market development
3. Finding out the relationship of bioeconomy and new entrepreneurship
4. Learning the basics of well-known approaches supporting bioeconomy transition
5. Overviewing the major challenges and opportunities for the development of bioeconomy

The idea of these objectives is firstly to be familiar with the concept of the bio-based economy. To study the potential of the bio-based market, the author will analyze the market development from demand and supply perspective as well as explore the different categories of bio-based products. The thorough understanding of the bioeconomy concept and the bioeconomy market will be the foundation of the third objective, which answers the question of how future businesses should leverage the bio-based economy opportunities. For further study, several supporting approaches for the transformation into bioeconomy as well as the government roles will be briefly discussed. The last objective is to address many opportunities as well as constraints in the development of the bio-based economy.

2.3 Boundaries

The bioeconomy study, in theory, has a connection with several fields such as economics, chemistry, biology, politics, environmental studies that should be discussed to fully understand the concept. However, the author will not delve into these fields. Besides, several research approaches applied in bioeconomy development will not be mentioned in the thesis. The focus is still studying the bioeconomy fundamentals; the bio-based market, and the bioeconomy entrepreneurship. This thesis is intrinsically a handbook of many basic concepts in bioeconomy, thereby does not go into detail of a certain subject that involve in bioeconomy.

2.4 Research Questions

Research questions will be split into two groups: the concept and the bio-based market.

1. BIOECONOMY CONCEPT
    1. How is bioeconomy defined?
    2. What kind of resources are used?
    3. How is the value chain defined?
    4. What are those primary productions applied in the bioeconomy?
    5. What are the methods used in biomass processing?
2. BIOBASED MARKET
    1. What is the sustainable development problem and the bioeconomy in promoting sustainable development?

2. Describe the bio-based market through demand and supply point of view and define major products?
3. How does future entrepreneurship make use of bioeconomy opportunities?
4. What are the approaches applied to support the bioeconomy transformation?
5. What are the major bioeconomy challenges and opportunities?

2.5 Conceptual Framework

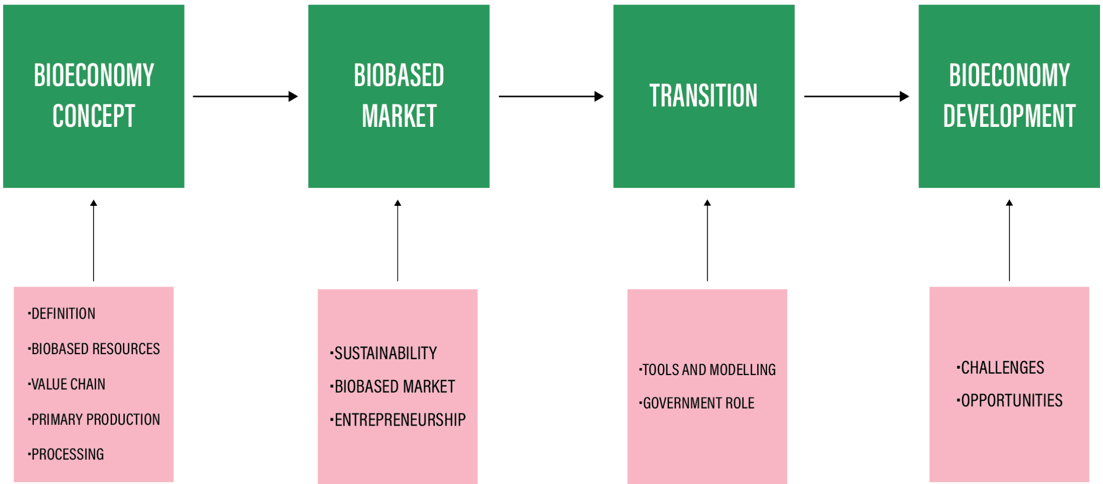


Figure 1. Conceptual Framework

This conceptual framework illustrates the four main sections in the theoretical part. The bioeconomy concept explains bioeconomy definition, bio-based resources, bio-based value chain, primary production, and processing of biobased resources in detail. In other words, this block will answer every question in the first part of the research question. The second block discusses the development of the bio-based market and its major products. The big picture of sustainable development will underline the importance of the transformation into a bioeconomy. The understanding of the bio-based market and sustainable development will be the basis for the investigation of entrepreneurial ventures. The third section deals with transforming bioeconomy knowledge. Well-known approaches that are applied in the transforming practice will be introduced. Along with these approaches, the role of government is pointed out as well in supporting bioeconomy and sustainable development. The final section sums up the theoretical background by an overview of challenges and opportunities in the bioeconomy development.

3 BIOECONOMY CONCEPT

3.1 Definition

Bioeconomy has several names known as bio-based economy or knowledge-based bio-economy. This concept refers to an economy where its materials, chemicals and energy are taken from biologically renewable resources. Bioeconomy has the potential to respond environmental, social and economic challenges. This concept provides best opportunities for firstly, biotechnologies that can be applied in production for higher productivity, for example, in agriculture to meet future demand and secondly, transformation from fossil-based economy into bio-based economy with renewable resources. During the concept development, the term “knowledge-based” was also added into the definition as “knowledge-based bioeconomy”. The knowledge-based bioeconomy aims at achieving an economic development with “high-technology industries, which requires investments in innovation and highly skilled labours”. (Birner 2018, 20). Besides, the development of this concept also emphasizes the two perspectives of bioeconomy: “the resource substitution” and “the biotechnology innovation”. The resource substitution perspective focuses on the scarcity of fossil fuels. This calls for the substitution of fossil resources by renewable resources. Meanwhile, the biotechnology innovation perspective highlights the role of biotechnologies in economic development, employment, energy supply, and the improvement in living standards (Birner 2018, 19- 20).

Bioeconomy has developed into a global concept. There is an increasing trend that not only industrialized but also developing countries have had their bioeconomy-related strategies and policies. Regarding scientific literature, more and more publications relating to bioeconomy topic have been considerably risen as well (Birner 2018, 21-22).

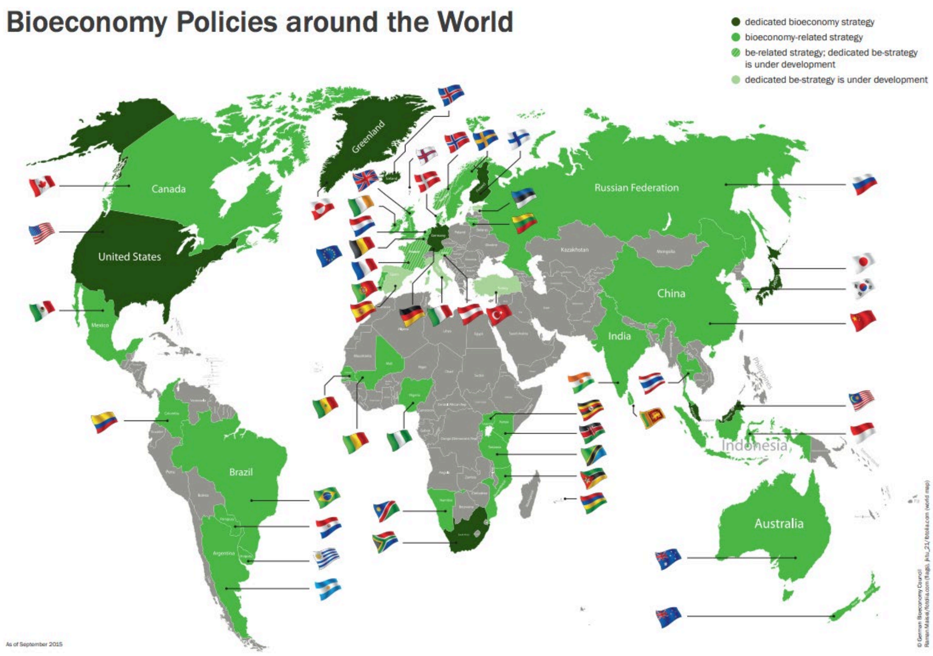


Figure 2. Bioeconomy around the World (Website of Global Bioeconomy Summit 2015 2019)

3.2 Biobased Resources

Biomass origin

Biomass as known as biobased resources originate from organic sources: plants, animals, microorganisms, algae, and organic wastes. Biomass is formed through the process of photosynthesis in which plants and green algae transform light energy into chemical energy. The main products of photosynthesis are oxygen and sugars. Depending on biomass origin and specific demands, bio-based products can be achieved by relevant methods (Zörb & Lewandowski 2018, 77).

Biomass characterization

The classification of biomass resources can be based on their origin (plants, animals, algae or microorganisms). When it comes to biomass products, their characteristics and production requirements are both very distinctive from each other. This is also true for ethical perspectives such as "meat" biomass is not accepted by the plant-based community. Biomass resources can also be classified by their sectors which they are made from for example agriculture, forestry, fishery, and aquaculture. The competition for food supply brings out the necessity of the best use of biomass. Hence, "edible" and "non-edible" biomass classification is also needed. Biomass major component e.g. sugar, starch, oil, protein, cellulose is the most appropriate criterion for the biomass classification in terms of biobased product chains. Physical condition is also considered as one criterion for classifying biomass. These physical conditions can be "wet", "dry", "solid" and "liquid". The requirements for e.g. processing and storage are determined by biomass physical condition. (Zörb & Lewandowski 2018, 80-82).

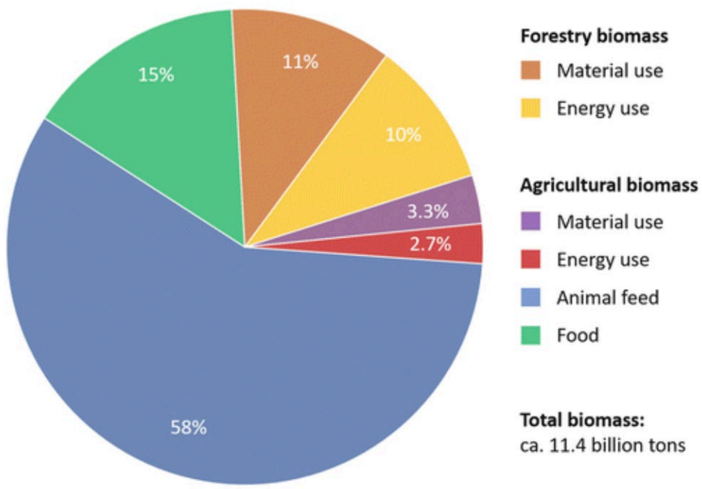


Figure 3. Worldwide use of harvested forestry and agricultural biomass in 2008 (Zörb & Lewandowski 2018, 83)

The diagram shows the total estimated global biomass and its use from the forestry and agricultural sector. There are about 11.4 billion tonnes of biomass produced every year, which include wood (18%), agricultural production (40%), pasture (30%) and by-products (12%). Approximately three quarters of agricultural biomass is used for animal feed production. (Zörb & Lewandowski 2018, 83).

Biomass characteristics improving techniques

Breeding is "the application of genetic principles in animal husbandry, agriculture, and horticulture to improve desirable qualities" (Website of Britannica 2019). This method is still one of the most important ways for producing food sustainably and sufficiently. Different crop characteristics such as yield, resistance to pests and diseases, fertilities, adaptation can be achieved through breeding methods. There are two majors of them: "conventional" and "genetic engineering" methods. The former aims to improve either varieties or breeds. The latter is used to modify organism's genome (genetic material) with biotechnological techniques (Zörb & Lewandowski 2018, 84).

Genetic Engineering

Genetically modified organisms (GMOs) refer to organisms whose chemical structure has been modified to achieve desired characteristics (Website of Britannica 2019). Genetic engineering techniques can be widely applied to crops with the purpose of chemical structure modification. This method brings several advantages; however, GMO production is not certified in organic agriculture and accepted around Europe (Zörb & Lewandowski 2018, 84).

Biological knowledge

Biological knowledge is the process of combining biological information and interpreting its meaning. This process is carried out by bioinformatics which applies computational and mathematical tools to organize, store and analyze biological data.

Biological knowledge is valuable for such knowledge-based bioeconomy because of the practical data for developing processes in for example pharmaceutics and crop productions (Zörb & Lewandowski 2018, 85).

Synthetic biology

Synthetic biology is the application of genetic engineering and biotechnology to develop novel, non-natural biological components, and systems with desired characters or redesign existing biological systems for new purposes. Synthetic biology provides new prospects for bioeconomy, for example, more economical production of some products, products that cannot be produced by naturally biological methods (Zörb & Lewandowski 2018, 86).

3.3 Value Chain

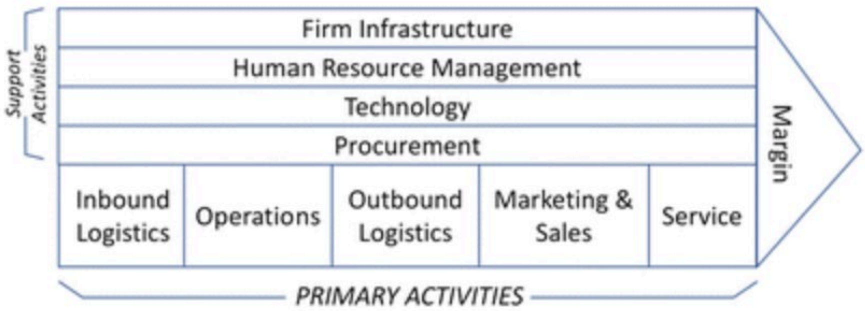


Figure 4. Michael E. Porter's original value chain model (Kindervater, Göttert & Patzelt 2018, 88)

The Porter's value chain describes a process included various activities from a product/service conception to final consumers and disposal after use. The *bio-based value chain* shares the same idea with the original value chain definition. However, as the intricate processing procedure of raw materials in bioeconomy, which means their inclusion in the value chain would cause the incomprehension. Therefore, the biobased value chain below is the simplified version with major activities including primary production, conversion, and markets. In this way, it would be easier to read, yet, cause the loss of information. In addition, a value network that integrates several value chains enables the demonstration of such products made from various raw materials (Kindervater, Göttert & Patzelt 2018, 87-89).

Figure 5. Simplified biobased value chain (Kindervater, Göttert & Patzelt 2018, 89)

Below are simplified bio-based value chains of food, fuel, and fiber production.

Figure 6. Dairy production (Kindervater, Göttert & Patzelt 2018, 93)

Figure 7. Biogas production (Kindervater, Göttert & Patzelt 2018, 93)

Figure 8. Paper production (Kindervater, Göttert & Patzelt 2018, 93)

Value-added chain is another name of value chain. In a value-added chain, additional information such as product chain, process chain, information flow is included. Product chain illustrates the transformation from raw material(s) to a final product. Process chain shows extra processing phases to achieve essential intermediates. Information flows are those about economic, social, and environmental impacts that originate from a product. From an economic viewpoint, the value-added chain assists stakeholders in understanding the cost structure and socioeconomic value of a product in a detailed manner (Kindervater, Göttert & Patzelt 2018, 88-89).

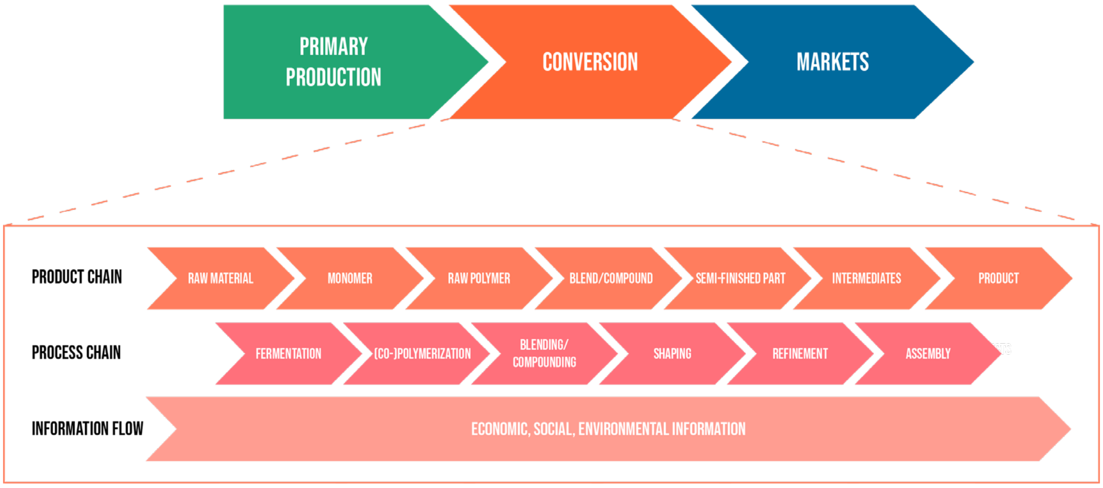


Figure 9. Simplified value chain with product chain, process chain and information flow of bio-based plastics (Kindervater, Göttert & Patzelt 2018, 90).

Biobased value chain characteristics

As the bioeconomy aims to use renewable resources sustainably, *cascading use* is believed to hold potential for this purpose. *Cascading use* is the maximization of renewable resource usage. Additionally, cascading can be considered as the multi-purpose use of biomass and the high-value biomass applications whose prioritization of biomass use is for foodstuff or healthcare purposes. One of the most prominent applications of the cascading approach is biorefinery, whereby biomass can be used efficiently to produce bioenergy and bio-products through different conversion processes (Kindervater, Göttert & Patzelt 2018, 90).

Characteristics of the biobased value chain are mainly received from the original resources. Agricultural and forestry biomass sectors are typical examples. They are all impacted by environmental conditions, therefore, the production processes have seasonal patterns. Besides, transportability is also considered as another typical pattern as the low density and perishable character of biomass. This shows a huge contrast to the fossil-based production processes (Kindervater, Göttert & Patzelt 2018, 93).

3.4 Primary Production

Primary production is a process occurring inside living organisms, which utilizes autotrophs from atmospheric and aqueous carbon dioxide (CO_2) to synthesize organic substances. *Primary productivity* indicates the rate of converting energy into organic substances, which is affected by both internal and external factors. Moreover, this indicator also varies from species. Due to the growing bioeconomy that requires a tremendous demand for biomass supply, higher productivity is always expected. Yet, the debate on the use of biomass for food supply and other uses such as energy and materials creates clear rules to determine the priority of biomass production and use:

- Potential biomass should not be in the conflict with food production
- Biomass should not be produced in areas of conservation
- Biomass should be produced more efficiently through leveraging available resources as well as residue streams and improving conversion techniques (Lewandowski, et al. … 2018, 97-100).

Agriculture and forestry are the two major biomass production sectors. Fishery, aquaculture, algae and microorganism sectors produce smaller quantities consecutively.

3.4.1 Agricultural Production

Agriculture is the cultivating of plants and the raising of livestock to produce food, feed, fiber and other desired products such as biomass for material and energy use. These agricultural productions are organized by farming entities inside the agroecosystem. *Agroecosystem* can be described as a natural ecosystem that is modified by man for agricultural activities such as crop production or animal husbandry (Website of ScienceDirect 2019). There are several factors impact on the efficiency of agricultural production systems:

- Production activity: crop, livestock or mixed production
- Form of organization: family farm, industrial farm, etc.
- Climatic and environmental conditions

Socio-economic factors (land availability, farm and market structures) (Lewandowski, Lippe, Montoya & Dickhöfer 2018, 102-103)

Agriculture and Climate Change

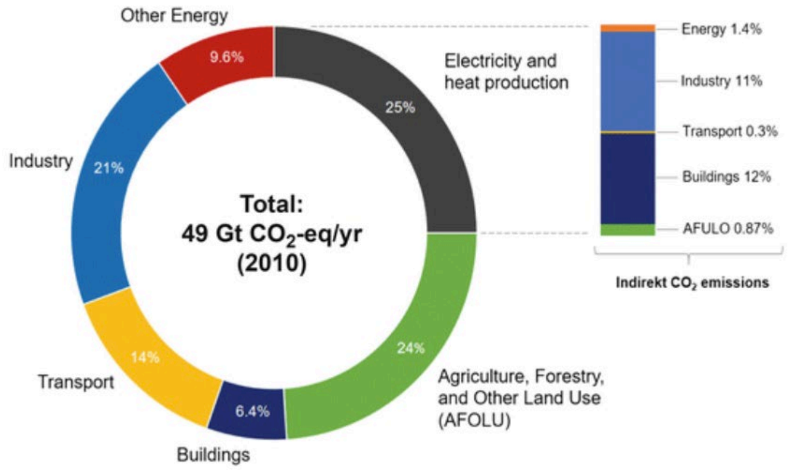


Figure 10. Total greenhouse gas emission from economic sectors in 2010 (Lewandowski, Gaudet, Lask, Maier, Tchouga & Vargas-Carpintero 2018, 8)

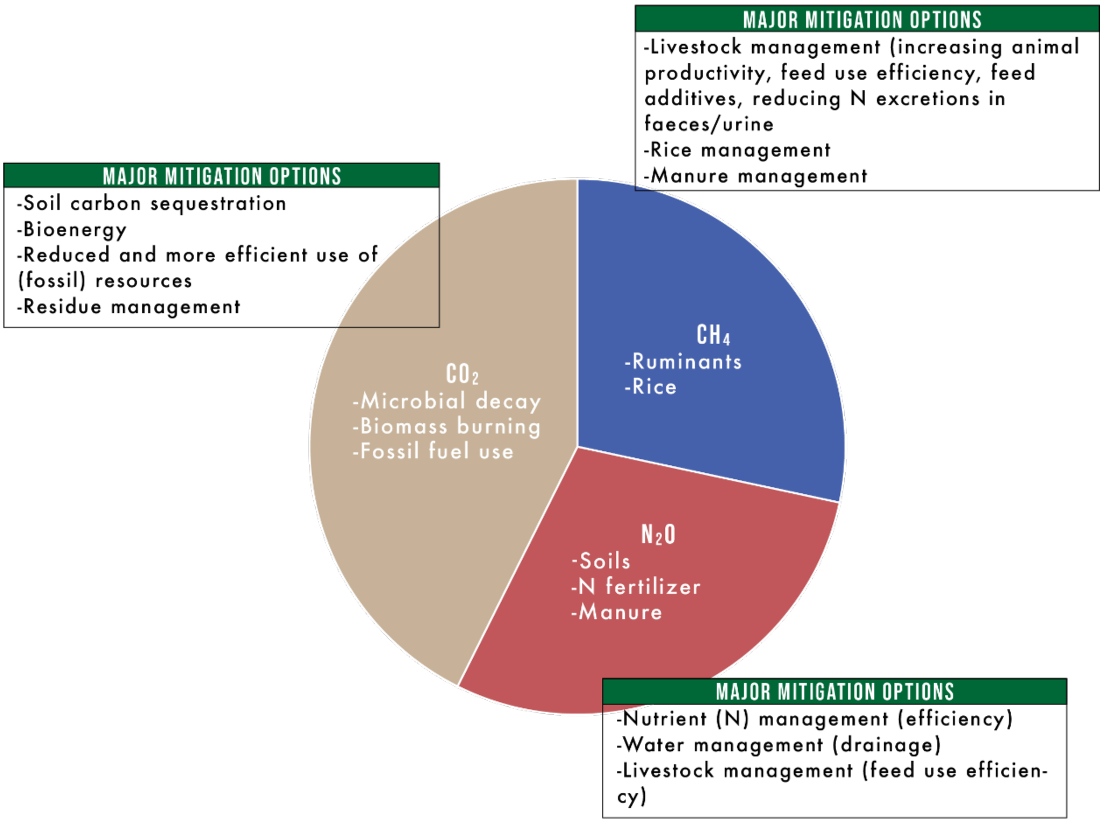


Figure 11: Greenhouse gas emissions from global agriculture (Lewandowski, Lippe, Montoya & Dickhöfer 2018, 125)

The emission of greenhouse gasses in agricultural production should be reduced by:

- maximizing the productivity in agricultural production by better conversion techniques; utilizing available resources, etc.
- efficiently managing agriculture inputs for example fertilizers, pesticides, energy, machinery into the production system
- enhancing land management, residue management, water management, etc.

considering bioenergy as an alternative in production (Lewandowski, Lippe, Montoya & Dickhöfer 2018, 125).

3.4.2 Forestry

Forests take up mostly 30% of the world's surface and are one of the world's most important ecosystems. Forests store a remarkable carbon volume that is estimated as much as the atmosphere. Furthermore, forests have several roles relating to human livelihood, biodiversity conservation, protection for soil and water, building materials, natural resources provision; for example, food, feed, energy. *Forestry* is the practice and science of understanding and managing forests. This includes the responsible use of natural resources that are associated with forests. Forests have an essential role in the present and future bioeconomy as the provision of huge sustainable and renewable resources. Moreover, forests are of few biggest carbon sinks and play their role in mitigating climate. Thus, a general forest definition should be considered these listed criteria:

- Forest is an area covering a large collection of trees that are everlasting, woody and erected.
- Forest has its own "forest climate" that is much different from the open land's so that temperature and humidity are relatively balanced. Soil properties are much better in terms of organic matters and such.
- Different types of forests are characterized by different habitats and ecologies that support the existence of plant and animal community (Langenberger & Lippe 2018, 128).

Forests not only provide the habitats for human livelihoods and animals, but also protect watershed; prevent soil erosion, and mitigate climate change. Wood is the major physical resource that has changed mankind's history as an energy source.

Wood as a primary element for supporting human livelihood remains the same until now. In bioeconomy, it is essential to understand the composition as well as the features of wood. Three main components of wood are cellulose; hemicelluloses and lignin. Regarding the chemical perspective, wood contains carbon, oxygen, hydrogen, nitrogen and some minerals. With distinctively physical and chemical characteristics, wood can be applied for a wide range of purposes. Beside energy use, wood is such a multi-purpose material for such as construction, paper, furniture, ornament, food materials (sugar, flavoring agent, etc.) (Langenberger & Lippe 2018, 136-138).

CHEMICAL COMPOSITION OF WOOD	
CARBON	50%
OXYGEN	43%
HYDROGEN	6%
NITROGEN	1%, incl. minerals

Figure 12. Chemical Composition of Wood (Langenberger & Lippe 2018, 138)

In respect of sustainable forest management, the exploitation of forests for the economic purpose should be under control. Many parts of the world's forests have been dramatically lost due to the anthropogenic impacts. This tremendously affects the biodiversity, the ecosystem, and the livelihood of many species including humans'. For future bioeconomy, forest degradation would be a huge threat. Therefore, forestry management regulations should be developed and implemented, especially in developing countries or tropical areas where forests are one of the main sources of human livelihood. Additionally, the promotion of world challenges and awareness of people towards the environment and forests would help to deal with the sustainable use of forests (Langenberger & Lippe 2018 141-144).

3.4.3 Aquaculture

Aquaculture can be understood as the farming of aquatic animals with economic, recreational or other purposes. Aquaculture activities take place in water environments that can be rivers, ponds, lakes, ocean, or man-made closed systems inland (Website of National Oceanic and Atmospheric Administration 2019).

Aquatic animals are rich with nutrients and provide a healthy diet; therefore, the demand for aquatic food consumption and feed products has increased rapidly. The high demand for aquatic food consumption has led aquaculture to the number one food production with the fastest growth globally. At the same time, the biomass from the aquaculture sector has not changed that much over the past decade. When it comes to aquaculture production systems, it can be generally classified into three major systems based on their intensity: extensive, semi-intensive, and intensive. Aquaculture production systems highly associate with spatial factors such as production location, production scale (Pucher 2018, 145-147).

Extensive aquaculture applies for growing aquatic organisms such as mussel, oyster, seaweed with low demand for external inputs (feed, fertilizers) and mainly grow by natural feed sources. The stocking density is low due to limited natural feed resources in natural environments. These extensive systems do not require a high level of technical equipment as well as management. This method can only be applied if natural water areas are rich and not contaminated, which is important for biological preservation purposes. *Semi-intensive aquaculture* happens in either natural or constructed pond environments where aquatic organisms such as catfish, carp, prawn are grown by both natural feed supplies and external supplies through fertilizers. The stocking density is much moderate compared to the intensive type of aquaculture. The medium management level is the optimum requirement in semi-intensive aquaculture. Extensive and semi-intensive aquaculture often takes advantage of polycultures that combine several species in the same environment. *Intensive aquaculture* uses for producing carnivorous aquatic animals for example shrimp, salmon in monocultures (one aquatic animal is grown at a time) by external feed resources only. This intensive system requires high technical management. Net cage and inland flow-through systems are main man-made environments applied in intensive aquaculture (Pucher 2018, 147-149).

Considering the various types and scales of aquaculture production systems, aquaculture has a huge impact on the environment. Additionally, the continuous growing demand for food consumption and feed would make aquaculture production more intensive. Thus, the focus on environmental, economic, social sustainability in aquaculture is extremely important. Risk management is necessary for aquaculture production to prevent potential risks as well (Pucher 2018, 153).

3.4.4 Microalgae

Microalgae are known as a group of plant-like, single-cell organisms and estimated around 300,000 species existing on Earth until now. They are the most important oxygen and biomass producers. Microalgae produce approximately 50 % of the global oxygen. In terms of biomass production, biomass productivity of microalgae is usually five-to-ten times higher than of any higher plants. In addition, freshwater consumption is one of those advantages in cultivating microalgae because of their ability to grow in brackish and coastal seawater. The microalgae production process is distinguishing from land-based animals since the growth is generally in controlled environments. Light is considered as the most important factor in the microalgae cultivation. Microalgae use light energy to transform carbon dioxide (CO_2) into high-value compounds (proteins, omega-3 fatty acids). It also depends on the species and the desired products that the cultivating system would be selected for certain purposes. They can be tubular reactors, flat-panel reactors or open ponds (Schließmann, Derwenskus & Schmid-Staiger 2018, 154-155).

Microalgae cultivation provides many materials that can be used for food and feedstocks, beauty products, and pharmaceutical ingredients, energies. Figure 12 shows typical compounds that can be applied in various sectors. In bioeconomy, microalgae biomass production is relatively challenging and high-cost since microalgae biomass contains more than one component that is needed for a specific application such as proteins and omega-3 fatty acids for food applications. Additionally, the productivity depends on the microalgae origin as well as the cultivation method. Hence, microalgae biomass in bioeconomy should be approached efficiently and completely (Schließmann, Derwenskus & Schmid-Staiger 2018, 157-160).

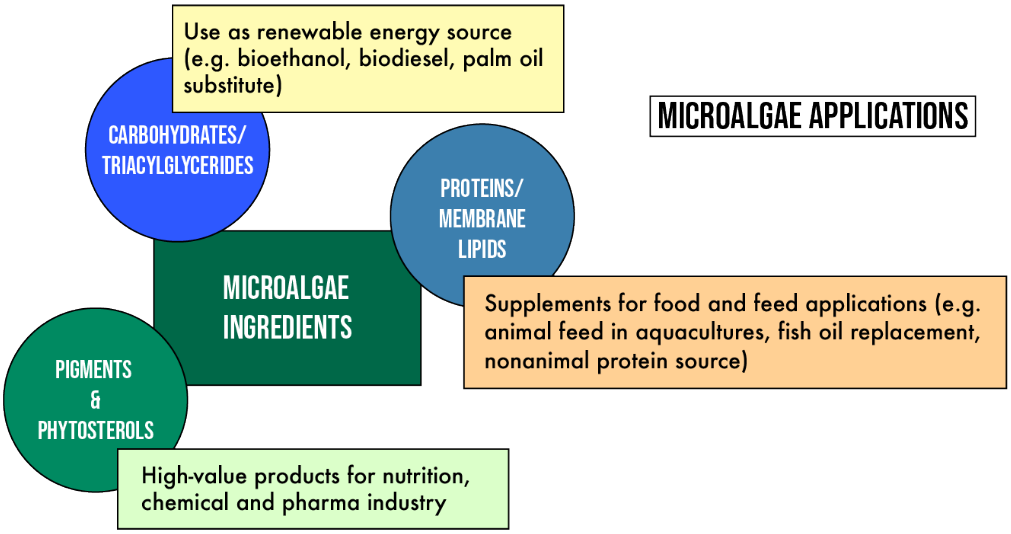


Figure 13. Microalgae applications (Schließmann, Derwenskus & Schmid-Staiger 2018, 159)

3.5 Processing of Biobased Resources

Bioeconomy attempts to convert or process bio-based resources into as many products as possible that can be applied in different sectors, for example, food, feed, energy, and materials. Food supply production is the most fundamental and traditional function of bio-based resources. The industrialization has majorly changed how food is processed, technologies applied in these processes, and how they are packaged and preserved. In a general sense, the development of food science and technology elevates food matters when it comes to physical, chemical, and biological processes that improve food quality and safety. Our current economic system heavily relies on fossil resources (crude oil, coal, natural gas). In bioeconomy, renewable feedstocks (plants mostly) are the main resources to produce bio-based materials. At the same time, the biorefinery is one of the major concepts to replace oil by biomass to produce energy and chemicals. Biorefinery concepts develop new methods for converting biomass into fuels, energy, and materials that can be substituted for fossil-based products. Besides biorefinery, thermochemical, and biochemical conversion are both initiated from biorefinery concepts but less in demand. In respect of energy and mobility, wind, solar, and geothermal energy have great potential. Though, renewable feedstocks are still the best choice for these purposes (Lewandowski, et al. … 2018,179-180).

4 SUSTAINABLE DEVELOPMENT, BIO-BASED MARKET AND ENTREPRENEURIAL VENTURE

4.1 Sustainability Development

Sustainability can be understood in a wider social context known as sustainable development. Sustainable development involves economic, environmental, and social factors. In other words, sustainable development aims at the balance between the development of the current generation and the security for the coming generations. Thus, this concept of sustainable development has a great influence on the formation of bioeconomy principles that cover these three dimensions (Hahn 2018, 250-251).
Sustainable development is about the integration of economic, environmental, and societal objectives. The United Nations has pointed out 17 sustainable development goals (Figure 14) that need to be achieved for a better future. These goals cannot be reached if we focus solely on a single aspect. Instead, the requirement for the integration of economic, environmental, and societal factors is vital for this sustainable development achievement.

Figure 14. Sustainable development goals (Website of Sustainable Development Goals Knowledge Platform 2019)

Furthermore, the promotion of sustainable development and sustainable development goals need the interaction of several actors. A company should embrace the concept of sustainability management which is ideal for its financial bottom line. The substantial support from different investors and shareholders is needed for sustainability management. Policymakers should integrate sustainable development goals into the regulations and policies. Organizations encourage their employee sustainable performances; influence shareholders through sustainable management. Consumers improve their awareness and change their behavior to contribute to sustainable development (Hahn 2018, 249-255).

Regarding societal transformation, bioeconomy is one essential element that can facilitate this transformation. The demand for a bio-based economy has been growing recently as its value and consumer's preferences. Hence, the requirement of a transformation from a current economic system into a new system that highlights the economic, environmental, and social sustainability is certain. Bioeconomy, in this regard, shows its potential to make this transformation happen (Birner 2018, 28-30).

4.2 Bio-based Market

Bio-based products have been received lots of attention due to the finite fossil resources and climate crisis. For the EU market only, the bio-based product sector has been declared as the most potential area for sustainable future growth. However, bio-based market growth generally does face several limits.

Nowadays, the environmental impacts caused by the fossil-based industries concern the consumer more and more. It is unavoidable that natural resources could not fulfil future demand. An economy that does not rely on fossil-based resources; protect and preserve the environmental values; mitigate climate change, and secure the well-being of the next generations should be created. The bio-based market which has similar characters, thus, has developed as a potential sector in the market. In contrast, the bio-based market development cost is much higher that of traditional markets. This practice shows that bio-based products struggle to gain its market share because of not only cost factor but the socioeconomic situation. In addition, there is still a shortage of standards, certifications and labelling programs for biobased products that differentiate their higher value and prices towards traditional products (Urban, Boysen & Schiesari 2018, 233-235).

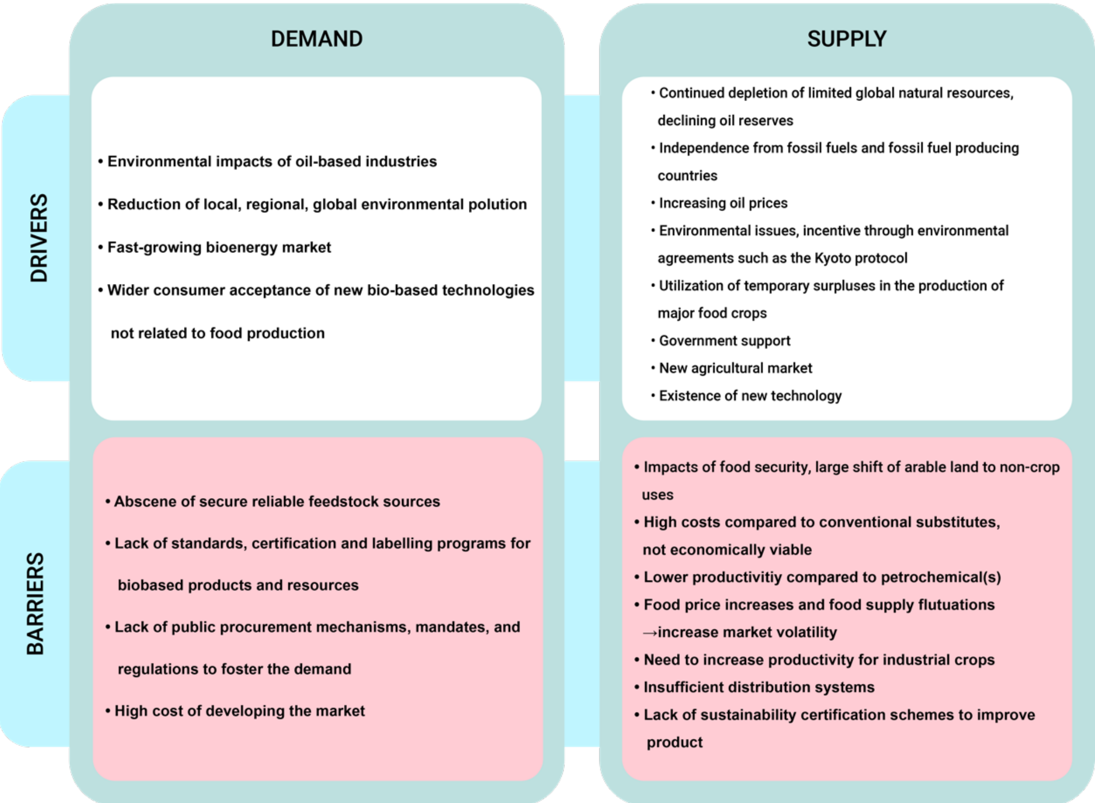


Figure 15. Major drivers and barriers in demand and supply of biobased resources and products (Urban, Boysen & Schiesari 2018, 235)

From the supply point of view, the development of bio-based market responses many sustainable development goals. The dependency on fossil resources as well as oil-producing countries would be reduced. Plus, several major environmental problems would be slowed down by climate change prevention, non-biodegradable wastes reduction or landscape preservation. Additionally, governmental support through new policies and regulations is a key factor for the bio-based market success. And then, new technologies play their role in facilitating the new generation of products that are sustainable. Alongside these prospects, the shift to a bio-based market would require continuing effort to maintain this sector in the whole economy. Besides, the conflict between food security and bio-based materials poses another threat to the bio-based market. Although bio-based products are sustainable, they are still less competitive than traditional products due to higher market prices. In terms of productivity, bio-based production is much complex and time-consuming so that high productivity is hard to achieve. Therefore, continuous research and development are essential for the competitiveness of the bio-based market (Urban, Boysen & Schiesari 2018, 233-235).

Biobased products

In 2008, the global agricultural land use was allocated 18% for food production, 71% for animal feed, 4% for biofuel, and 7% for biomaterials (Urban, Boysen & Schiesari 2018, 239).

According to OECD definition, biobased products are those made from biological resources, forestry materials, and renewable agricultural materials which can be from plants, animal wastes, and marine materials. Food and feed are not counted as bio-based goods in this case. Biobased products can be categorized into three major groups: biofuels, biochemical, and biomaterials as shown in Figure 10. Biofuels market which has existed for mostly three decades receives more attention and is more prominent than biochemical and biomaterials. Both biochemical and biomaterial markets are considered as infant industry but gradually growing with the market recognition (Urban, Boysen & Schiesari 2018, 233-236).

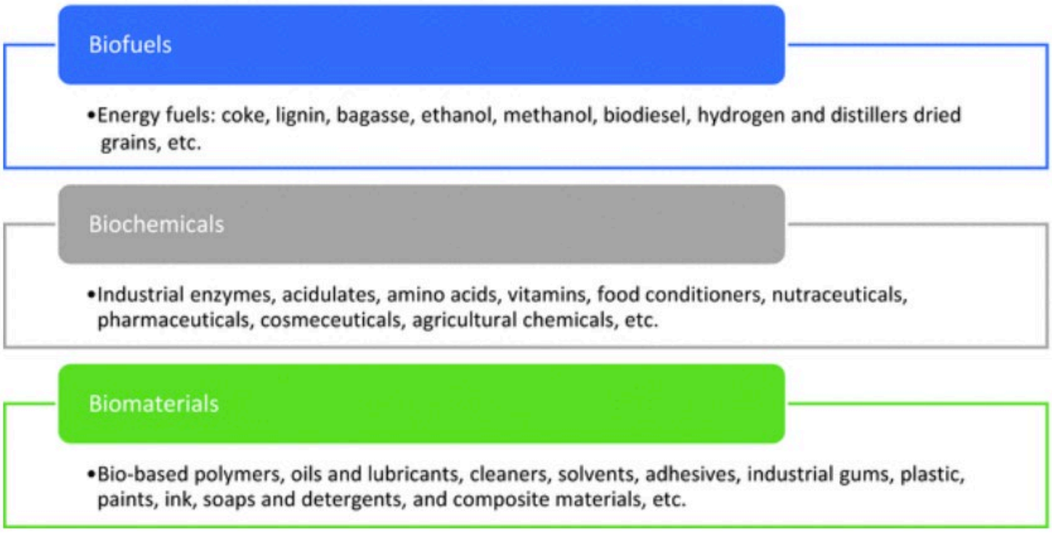


Figure 16. Biobased products (Urban, Boysen & Schiesari 2018, 236)

Biofuel has been present in the world long ago, however, cheaper fossil-based energies made the market entry much challenging for bio-based fuels. Biofuel, on the other hand, is the ultimate solution to tackle spiking oil prices and climate change. Global liquid biofuel production has drastically increased during the last three decades. Ethanol and biodiesel are those two well-known liquid biofuels. Figure 16 illustrates the development of ethanol and biodiesel production from 2007 to 2015. It is estimated that the total amount of global biofuel production was 146 billion litters in 2015, with 80% of ethanol production. Biofuel production is accounted for 1% of the world's cropland in 2016. North America was the largest supplier, followed by Latin America including the Caribbean and European Union respectively during this period. The production of biodiesel and ethanol is predicted to continue increasing by 11.1% and 31.1% in 2025 (Urban, Boysen & Schiesari 2018, 235-236).

Based on Statista, in 2018 The U.S. is the leader of top countries with approximately 38.1 million metric tons of oil equivalent. The second top biofuel producer is Brazil with roughly 21.4 million metric tons of oil equivalent. Indonesia, Germany, and China are among the global major biofuel producers as shown in Figure 17 (Statista: Leading countries based on biofuel production in 2018).

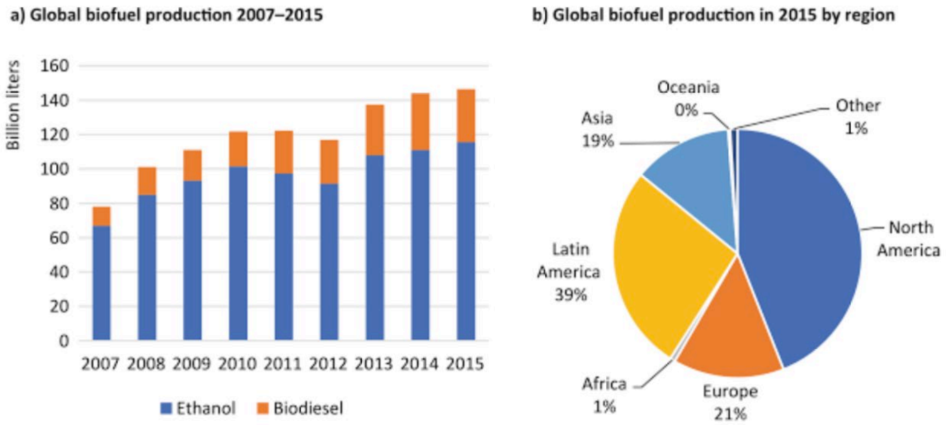


Figure 17. Global liquid biofuel production development (Urban, Boysen & Schiesari 2018, 236)

Renewable natural gas as known as bio-methane is one of the potential bio-based gasses that could be widely used in transportation, electricity and heat generation (Website of National Geographic 2019). The development of bio-based fuels (liquid-based and gas-based) brings about a new horizon in clean energy and solutions for global challenges such as climate change, fossil resource exhaustion.

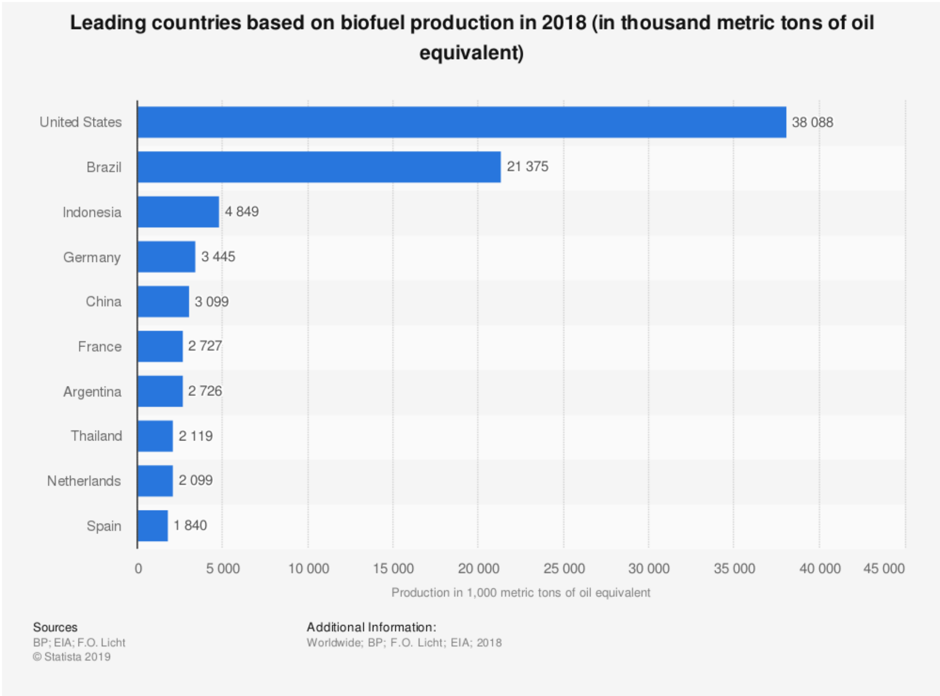


Figure 18. Leading countries based on biofuel production in 2018 (Statista: Leading countries based on biofuel production in 2018)

In respect of the biochemical market, more and more bio-chemicals have been produced from biomass nowadays. The diversity of biochemical sets the standard for the classification of the biochemical market. The total sale of bio-chemicals made from bio-based materials in the chemical industry soared up to EUR 48 billion which only represented nearly 3.47% of the total output in 2007. EU 27, North America (Canada, the U.S., and Mexico-NAFTA), and Asia were the strongest players in this bio-chemicals market with the contribution of up to 90% of the global sale. Meanwhile, other parts of the world accounted for 10%. Active pharma chemicals, cosmetics, organic chemicals are those three dominant sectors in the biochemical market as shown in Figure 19 (Urban, Boysen & Schiesari 2018, 238).

The EU is the most dominant player in this market, which is followed by the U.S. and Asia. In 2013, the bio-based chemical product amount was estimated at around 6% of the total chemical products (Urban, Boysen & Schiesari 2018, 238). For the EU market, it is expected that the bio-based chemical market annual growth rate could reach approximately 3.6% during the 2019-2025 period (Website of European Commission 2019).

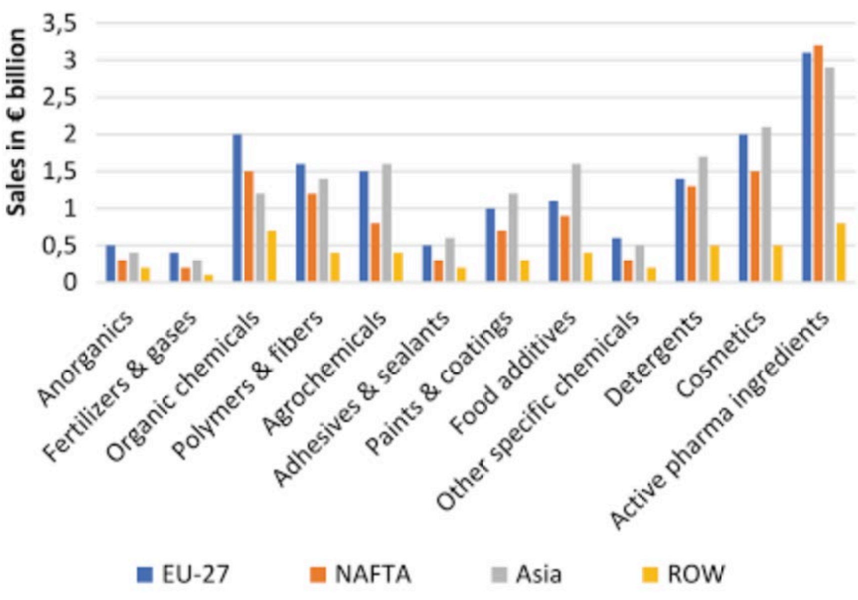


Figure 19. Bio-chemicals market 2007 in EU-ROW: rest of the world (Urban, Boysen & Schiesari 2018, 238)

In the biomaterials market, bioplastics gain the most share and quickly grows. Bioplastics are made from renewable sources such as starches, vegetable fats and oils, and cellulose. In 2013, bioplastics only accounted for a very small fraction of the annual plastic amount produced around the world around 1% of 300 million tons of global plastics. However, the recent high demand for bioplastics has boosted bioplastics production at around 4.1 million tons in 2016. This amount is predicted to reach 6.1 million tons in 2021. It is revealed in Figure 19 that Asia was the leader of the 2016 bioplastics market with 1.81 million tons. The other two players Europe (1.31 million tons) and North America (0.97 million tons) followed behind. In 2014, about 1% (0.68 million hectares) of the world's agricultural land was used for bioplastics production. Bio-based Polyethylene Terephthalate (PET) and Polylactic Acid (PLA) are the two dominant and fastest grown biobased plastics in the bioplastics industry (Urban, Boysen & Schiesari 2018, 238-239).

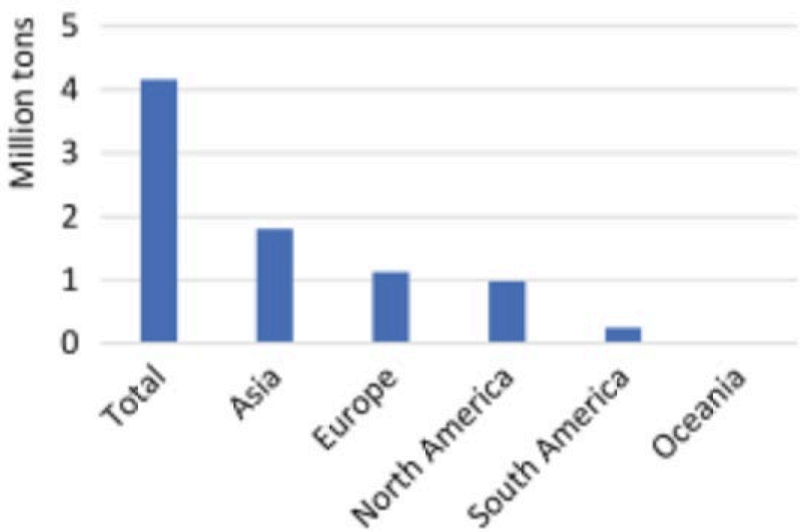


Figure 20. Global bioplastics production in million tons in 2016 (Urban, Boysen & Schiesari 2018, 239)

4.3 Entrepreneurship in Bioeconomy

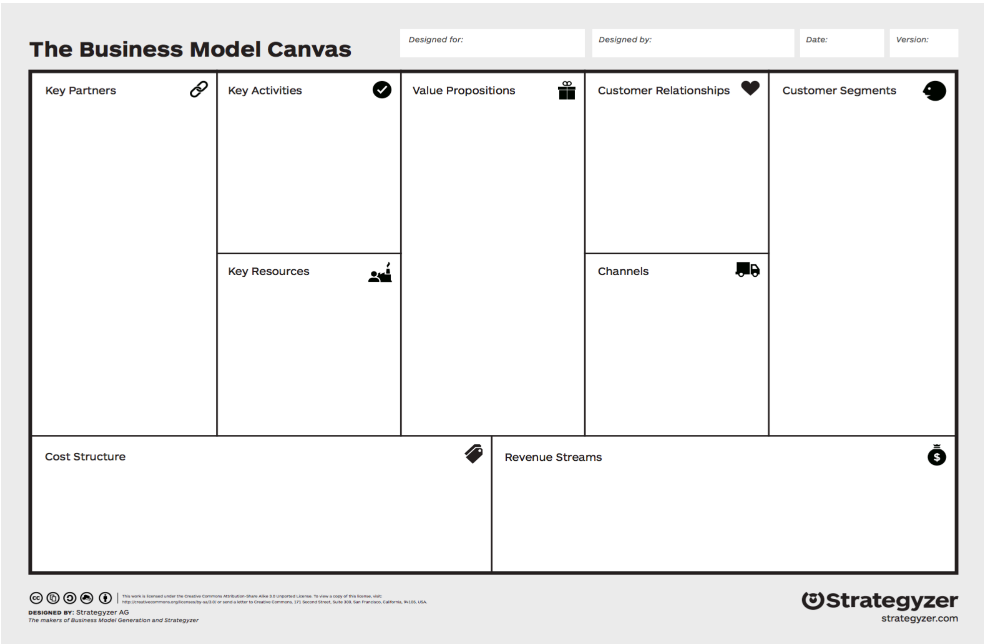
Entrepreneurship is the ability to establish, manage, maintain a business venture along with its potential risks to make profits (Website of Business Dictionary 2019). *Entrepreneurial opportunity* largely comes from market failures. In bioeconomy, recognizing global challenges that we are now confronting and the limits of the current economy are both important for the development of bioeconomy. Despite the awareness of the planet vulnerability caused by the current economy, business practices are not able to avoid market failures. Governments, therefore, have their roles to support entrepreneurs to reduce such market failures. Entrepreneurs learn from these failures to find out market opportunities (Kuckertz, Berger & Reyes 2018, 275-276).

The likeliness of bioeconomy providing potential entrepreneurial opportunities is enormous. However, entrepreneurs need to thoroughly evaluate those opportunities to ensure their feasibility as well as profitability. The assessment for entrepreneurial opportunities should consider these questions:

1. Where value can be created for customers?
2. Where the opportunity meets competence and experience?
3. Where customers would pay more?
4. Where opportunities would work in such a growing market?
5. Where risk and potential are balanced? (Kuckertz, Berger & Reyes 2018, 278)

Since the traditional market research approaches often deliver unlikely insights to entrepreneurs about the feasibility of a product or service, developing and testing a product from the early stage of a business is the most likely optimal choice for all start-ups. *Lean start-up method* is one of the most powerful approaches allowing a start-up to reduce unnecessary steps during the start-up process. This method starts with the assumptions of customer desires and potential markets. These assumptions are then validated by future customers. *A minimum viable product* would be finally created from the learning and market failures throughout the start-up process. The minimum viable product serves as a prototype that can bring feedbacks from potential customers so that the start-up can test their assumptions on the actual market needs. In bioeconomy, this practice is extremely crucial because of its nature of innovative products. Both entrepreneurs and consumers should cooperate to come up with a practical business model (Kuckertz, Berger & Reyes 2018, 278-279).

Business model canvas is another great tool to create and develop business through nine important components (Figure 21) that interact with each other to build on and capture the potential value of a new business. Customer segments are business's future customers whom businesses aim to deliver their products or services to. Value propositions refer to the core value that businesses provide customers to satisfy their needs. Channels are where businesses connect and communicate to their customers or customers can be able to reach a business for their demand. Customer relationships are the kind of relationships a business tries to build on with based on specific purposes. Revenue stream means the money returned from customer segments through value propositions offered to them. Different customer segments bring different revenue streams that contribute to the overall revenue. Key resources are generally those needed to function in a business. Key activities tell about activities that are performed to run a business. Key partnerships include all people and organizations that relate to the operation of a business. Cost structure points out all the costs that are involved in



building a business (Kuckertz, Berger & Reyes 2018, 280-282).

Figure 21. The Business Model Canvas (Website of Strategyzer 2019)

Bioeconomy offers a variety of entrepreneurial opportunities for new and existing businesses. A market research plan with the assist of these two helpful approaches is ideal for every entrepreneurship to discover market gaps where they can fulfill with ideas of business that show big concern for sustainable development. At the same time, facing difficulties from several factors such as product/service ideas; customer awareness; price competition; product development is unavoidable due to the highly innovative nature of bioeconomy (Kuckertz, Berger & Reyes 2018, 280-282).

5 TRANSITION TO SUSTAINABLE, BIO-BASED ECONOMY

5.1 Supporting Tools and Modelling

To transform an economy is highly challenging since this practice involves several factors from economic, societal, political, and environmental perspectives. Thus, the need for knowledge-based tools and appropriate strategies is extremely crucial to support this transformation. The development of a potential strategy to transform a system is complex and challenging due to uncertainties. Therefore, access to tools like scenarios is universally important. Scenarios have been widely applied to identify the possibilities when it comes to complex future states. Scenarios strive to look at different future perspectives to define such uncertainties; establish potential future states and development practices. Likewise, other approaches known as integrated model approaches that combine scenarios with models (economic models) would explore the relationship between various components such as resources, production, consumption, markets, sectors, and environment (Angenendt, Poganietz, Bos, Wagner & Schippl 2018, 290-291).

Scenario Approaches

Scenarios provide several functions such as knowledge; communication; goal setting, and strategy formation. From a scientific viewpoint, knowledge function is the most essential with two features: analyzing systems through possible consequences of a scenario and integrating social objectives, values, and norms in building scenarios process. If stakeholders share their roles in scenario development, communication function works well in this case as they create a ground for discussions from different fields and perspectives. Then, looking from a strategic perspective, scenarios are ideal for developing specific goals as well as assisting strategy planning (Angenendt, Poganietz, Bos, Wagner & Schippl 2018, 292-293).

Scenario approaches are normally classified into three types (Figure 12):

	PREDICTIVE SCENARIOS	EXPLORATIVE SCENARIOS	NORMATIVE SCENARIOS
CHARACTERISTIC QUESTIONS	What will happen? What can be expected?	What could happen, if...? What is possible?	How can a specific target be reached?
AIM	To predict the most likely future?	To analyse the possible future	Analysis of paths to reach the target
METHOD	Extrapolation of trends	Identification of main drivers	Backcasting

Figure 22. Scenario Approaches (Angenendt, Poganietz, Bos, Wagner & Schippl 2018, 295)

Predictive scenarios predict the most possible future by such questions “what will happen?” and “what can be expected?”. The answer tends to be the forecast of future trends without the consideration of market changes and other relevant decision-making criteria. Meanwhile, *explorative scenarios* analyze possible futures without being likely or desired. The questions like “what could happen, if…” and “what is possible?” would be answered. To develop this scenario, the main drivers of the system development and the interconnection of the elements of the system will be defined. Assumptions about these drivers also play an important role during the progress. This approach mostly works for a long-term period (20-40 years). However, uncertainty factors are still huge obstacles especially in bioeconomy when all drivers of an economy might drastically change over time. Unlike predictive and explorative scenarios, *normative scenarios* aim to reach the target (specific future) by answering the question “how can be a specific target reached?”. In other words, a specific target is clearly defined through this scenario, however, this is not the most essential part of this approach. Such social transformations like bioeconomy are the most suitable object of study for normative scenarios. A common method for developing normative scenarios is backcasting which identified targets that are meant to be achieved by analyzing the present and past events to create possible policies for the target (Angenendt, Poganietz, Bos, Wagner & Schippl 2018, 293-296).

When it comes to transforming a complex system, scenarios are such great tools that assist discussions and decision-making processes. However, scenarios approach could fail to fulfil the formation of the desired future. This is because, firstly, scenarios are neither prediction nor forecast, which will not depict an actual future event. Secondly, scenario findings are usually not objective since scenarios developing criteria are set by scenario builders. Therefore, it is important to follow a set of criteria that are proposed when building scenarios:

- Plausibility: depicted scenarios must show their plausibility but not necessarily consider being likely or desirable.
- Consistency: different scenarios should not conflict with each other.
- Comprehensibility: scenario developments should not be too complex.
- Selectivity: different scenarios should present their different future designs.
- Transparency: all assumptions, decisions, and criteria in the development of the scenarios should be thoroughly explained (Angenendt, Poganietz, Bos, Wagner & Schippl 2018, 301).

Integrated Model Approaches

For the scenario analysis, modelling can contribute valuable insights. Until now, there is no holistic modelling approach for developing bioeconomy due to the high degree of interdisciplinary approaches and the matter of economic integration in the bioeconomy.

Economic Models

This will give a brief introduction of economic modelling approaches that are applied in the bioeconomy context where these approaches can be used in biomass demand and supply.

Macroeconomic Models

Computable general equilibrium (CGE) models whose idea was originated from the equilibrium theory, which can be simply explained as the search for the balance between demand and supply and normally used in trade analysis (Angenendt, Poganietz, Bos, Wagner & Schippl 2018, 303).

Example (GTAP-Global Trade Analysis Project)

GTAP is a global network of researchers and policymakers working in the coordination with the Centre of Global Trade Analysis and Purdue University, Indiana, USA. They developed a standard GTAP model which is a generalized CGE modelling framework with quality data. International trade analysis and the influence of trade liberalization are its main applications. International collaboration is the key to better data and analysis that lead to better policies This model shows the relation of various sectors of an economy, for instance, agriculture and energy in terms of bioeconomy. Bioenergy is a new sector of this model (Angenendt, Poganietz, Bos, Wagner & Schippl 2018, 303-304).

Partial equilibrium (PE) models focus on a specific market or sector, which are useful for the thorough understanding of that market or sector (Angenendt, Poganietz, Bos, Wagner & Schippl 2018, 303).

Example (ESIM-European Simulation Model)

ESIM is a multinational partial equilibrium model for the agricultural sector, which shows the agricultural production and the consumption; the first-stage processing activities; and the international net trade (Angenendt, Poganietz, Bos, Wagner & Schippl 2018, 305).

Economic Bottom-Up Models

Bottom-up models can be able to answer a variety of questions within the bioeconomy framework. These models mostly depict technical aspects such as technologies, processes of biomass production along with the behaviors of bio-economic players. In addition, these models work at different spatial levels due to the specific interest of the analysis; the availability of biomass; the economic and ecological effects; and the defined boundaries (Angenendt, Poganietz, Bos, Wagner & Schippl 2018, 305).

Example (Energy System Model- TIMES PanEU)

TIMES PanEU-Pan-European TIMES model has been used in various European energy system analyses. TIMES aims to optimize the energy system cost based on demands; technologies; and policy requirements. This is also a multinational model that covers all the data related to energy supply and demand (Website of Energy Systems Modelling Project 2019).

Ecological and Biophysical Models

It is unavoidable that the transformation from a fossil-based economy to a bio-based economy would lead to the increase of biomass demand in both agriculture and forestry. The biomass production in some countries would cause the conflict between economic benefit and environmental system. Moreover, the bioeconomy development must take economic aspects and ecological impacts into consideration. Thus, many models have been developed in response to this.

Biophysical models (process-based models) illustrate biological, geological, and chemical processes that happen in the environment. These models have their focus on different areas. Some analyze how the agricultural and forestry management systems impact the environment. Others examine various scales from plot to global levels of agricultural and forestry activities. Since the demand for agricultural and environmental policy assessment measures, some of these models were developed to meet this specific need. (Angenendt, Poganietz, Bos, Wagner & Schippl 2018, 307-308).

Example (EPIC- Environmental Policy and Integrated Climate)

EPIC was developed to study the impact of agricultural activities on erosion and soil productivity. This has been further developed to simulate water quality; climate change; nutrient cycling; and the impact of atmospheric carbon dioxide (CO_2). EPIC can also take other management practices such as crop rotations, vegetation systems, etc. into consideration (Website of Blackland 2019).

Integrated Assessment Models (IAMs)

Integrated Assessment Models study the interaction between human activities and the environment. They describe socio-economic systems; environmental systems; and the relation between these two systems. IAMs integrate different models so that they can cover several research disciplines and fields such as economics; agriculture analysis; energy analysis; etc. Therefore, the bio-economic developing scenario is more holistic owing to the integration of economic, social and environmental perspectives. (Angenendt, Poganietz, Bos, Wagner & Schippl 2018, 310).

Example (IMAGE-Integrated Model to Assess the Global Environment)

IMAGE simulates the global environmental consequences of human activities. It reveals the relationship of society; biosphere; and the climate system. IMAGE aims to study the long-term impacts of global change from socio-economic and environmental factors (Website of PBL Netherlands Environmental Assessment Agency 2019).

5.2 The Role of Government

The government is responsible for maximizing social welfare or improving the quality of life. A responsible government will not ignore the wellbeing of future generations while striving to maximize the present generation’s wellbeing. The government has its role in the responsibility to the environment as private sectors themselves cannot fulfil this environmental responsibility. Hence, social welfare can only be fully maximized with tremendous work from the government in different ways. Bioeconomy, at the same time, supports natural resources preservation and mitigates environmental pollution, which are of many sustainable development goals. However, considering the economic sector, private markets cannot successfully achieve these goals. Again, the government needs to support bioeconomy promotion and sustainable development goals (Ahlheim 2018, 317-321).

6 CHALLENGES AND OPPORTUNITIES

There are great potentials to transform the present economy; heal the planet earth and ensure the welfare of future generations. Despite this fact, such a transition to a knowledge-based bioeconomy would be an extremely challenging task. This section will present major opportunities as well as challenges of this movement.

Bioeconomy provides massive opportunities for growth and jobs especially in such coastal and rural areas. New businesses as well as innovation opportunities in agriculture (food production); aquaculture (blue biotechnology); forestry (integrated biorefineries); bio-product industry (biochemical, biopharmaceuticals) could be set up. However, a huge investment for proper technologies and production would also be a huge constraint for these businesses to start. Additionally, the transition will bring out socio-economic challenges that link to, for example; price sensitivity; farmers' welfare; trade balances (Bourguignon 2018, 3).

Biomass is renewable; however, the available amount of biomass is not yet defined. In other words, biomass remains is a finite resource as a matter of available land and freshwater. Bioeconomy applies different methods such as cascading use to optimize biomass usage. Thus, this could be the solution for material shortage when the world population has been rapidly growing. However, the competition for cultivating land and freshwater to produce biomass might cause adverse impacts on food production and food security. Furthermore, the competition between bio-products vs. petrochemical products; bioenergy vs. fossil energy would be much intense. Traditional products are generally affordable and well recognized by the whole population. However, a step further to bio-products is much challenging as only a portion of the population can access (Bourguignon 2018, 4).

Bioeconomy contributes massively to the goal of sustainable development as it slows down global warming and mitigates climate change by reducing greenhouse gas emissions. The transition to renewable energy would reduce a significant amount of greenhouse gasses. Plus, the development of agriculture and forestry would create more natural sinks for carbon storage. Regarding biotechnologies, many industrial wastes, plastics, and chemicals could be altered, which not only decreases production wastes and residues but also addresses new methods for better production that helps preserve natural resources. Nonetheless, bioeconomy might lead to carbon emissions in some ways such as deforestation for agricultural land use. Other aspects of life e.g. healthcare can be improved by bioeconomy, but the drawback to these might be the environmental impacts (biodiversity, ecosystem, soil and water quality) that should be underlined through the exploitation of bio-based materials (Bourguignon 2018, 4-5).

7 METHODOLOGY

7.1 Research Design

Research design is a general plan that assists in answering research questions(s) and reach the objective(s) of a research project. It includes a set of objectives based on research questions(s) and defines the sources of collecting data as well as the constraints that may have while collecting and interpreting data (Saunders, Lewis & Thornhill 2019, 172-176).

When the set of objective(s) is set, the researcher would determine to collect the data through either primary research or secondary research. Primary research involves different data collection techniques for instance interview, surveys, questionnaires, etc. which generate original data for the research. On the other hand, secondary research as known as desk research obtains data from secondary sources that are already published such as journals, published market research, governmental statistics, the internet, etc (Blythe 2012, 100). The main constraint of this thesis is to obtain primary data since the author does not involve in any specific organization. Thus, secondary research is more approachable. When it comes to methodology choice, the researcher will consider either to do quantitative research, qualitative research, or mixed methodology. Quantitative research, simply put, deals with numeric data (number) and utilizes data collection techniques such as questionnaire. Meanwhile, qualitative research makes use of non-numeric data (words, audios, images, etc.) and data collection methods for example interview. A research project is more likely to use a mixed methodology meaning quantitative and qualitative research are used (Saunders, Lewis & Thornhill 2019, 172-176). The ultimate purpose of this secondary research will be to enrich the understanding of bio-based economy topic through the examination of bioplastics. A qualitative research approach is the most suitable choice. Secondary research has the advantage of using published data in several forms. The qualitative approach in this secondary research will not require the researcher to reanalyze such as a survey which is unnecessary in this thesis. Moreover, the research process would be quicker and more convenient.

Secondary data gathering may be less time-consuming and cheaper; however, secondary sources usually do not provide everything that researchers need. Dealing with out-of-date or unreliable data is also one of the main drawbacks of second-hand sources. Consequently, it is necessary to be cautious and take great care of secondary data (Blythe 2012, 100-101).

7.2 Data Collection and Data Analysis

In this methodology, the author will continue a secondary study by qualitative approach on bioplastics. By this, the further study on bioeconomy topic will be more focused but still ensures the thesis coherence. The aim of the further research is to find out *why bioplastics become a trend nowadays.* Bioplastics is one of many important segments of the bio-based market. Additionally, they are, to some extent, familiar with the author as well as the readers because of their recent popularity. Thus, the search for data would be less challenging and more manageable. The author will conduct the secondary data collection based on chosen sub-questions as known as three primary categories below to generate findings that will help answer the big question.

- What are bioplastics?
- What have bioplastics offered (advantages and disadvantages)?
- How do bioplastics particularly affect consumer behaviors and business outlook?

This secondary study will utilize the archival and documentary research approach data collection technique. Archival research makes use of online archives, government and business data, etc. for further analysis in a research project. There is a wide range of archival and documentary materials which can be defined as textual, visual, and audio types. These can be both quantitative and qualitative data derived from original resources for other purposes. Secondary data collected are originally not for the research project, therefore, it must be careful in taking advantage of these sources. Adopting archival and documentary research can be handy and effective, however, using second-hand data may be challenging. Access restriction, out-of-date or unreliable data, commercial data are of many disadvantages from secondary sources (Saunders, Lewis & Thornhill 2019, 195-196, 254).

The author aims to collect data through the Internet mostly. Popular online news websites such as The Guardian, BBC have a wide range of articles and videos relating to bioplastics topic. National Geographic is also a great webpage where reliable scientific knowledge can be found. European Bioplastics webpage providing plenty information of bioplastics will be helpful as well. Along with these dependable sources, the author might access to other sources which will be referred later. Since this is a secondary study within a bioeconomy context, all the collected data will be compared if they replicate each other and are appropriate to the bioplastics topic as well as bioeconomy context. The author will then generalize the data into the research findings which will be in accordance with chosen sub-questions to answer the question *Why bioplastics become a trend nowadays.*

The research quality is then measured by reliability and validity. Reliability is the nature of being consistent in a research. A research is considered reliable when a researcher reproduces the research design and obtain the same findings. Validity examines the extent of being appropriate of measures applied, the accuracy of the result, and the generalizability of findings. When considering reliability, there may be a distinction between internal and external reliability. Internal reliability ensures the consistency of data collection through stages by several researchers in a research project. External reliability refers to the ability to replicate consistent finding results by researcher. A research is unreliable when there are biases and errors during research process, which impacts on research findings and conclusion. Reliability is important for measuring a research's quality, however, not sufficient to ensure a good-quality research. Validity is another key characteristic that a good research depends on. The extent of research findings that can be applied to the research problem discussion is internal validity. In the meanwhile, external validity refers to if research findings can be generalized for other relevant contexts (Saunders, Lewis & Thornhill 2019, 195-196, 213-216).

In this secondary research, to ensure the reliability and validity of research findings, the author will collect data through several trusty sources as shown above. To eliminate the risk of out-of-date and unreliable data, the author is going to firstly check the published date, the original source of the articles or online newspapers. After having all the up-to-date data, critical reading and comparing data based on three categories is the next step to sort out relevant and consistent data and generalize into findings. In this way, a secondary research result will ensure its quality of being reliable. The validity of this research is known as findings that are appropriate for the research question and other relevant research setting. Thus, the author will also justify his findings within the context of bioeconomy but still focus on the purpose of his secondary research.

8 RESEARCH FINDINGS

These findings will be based on three questions/categories that are listed above as a guideline in this secondary research.

8.1 What are bioplastics?

Definition

According to European Bioplastics, bioplastics indicate a family of materials with differing properties and applications. Biomass used to produce bioplastics is mainly from plants e.g. corn, sugarcane, cellulose, and microorganisms (What are bioplastics? 2018).

The term “bio-based” means a product or material is (partly) from renewable biomass. Biodegradation is a characteristic that links to chemical structure, not the resource origin. The property of being biodegradable depends on the environment conditions e.g. temperature, the material, or the application. A plastic material that is considered as bio-based may not be biodegradable. In other words, bio-based is not equivalent to biodegradable. In a nutshell, bioplastics are either bio-based, biodegradable or features these two characteristics (What are bioplastics? 2018).

Biodegradable plastics are thus (partially) derived from biomass (plants) and can biodegrade by occurring organisms such as fungi, bacteria, or in favorable composting conditions. The timescale and the environment must be specified otherwise the quality of being biodegradable of a plastic material (product) merely indicates its properties (What are bioplastics? 2018, 1, 4). Likewise, the term “compostable” refers to a characteristic of being able to compost under composting conditions. This could be either home compostability or industrial compostability. Thus, specific composting environment and timeframe must be clarified on a bioplastic product to ensure the accurate claim of compostability (Environmental Communication… 2017, 27).

The figure below represents three main types of bioplastics and their classification based on the biodegradability and bio-based content.

- *Bio-based and non-biodegradable group*: PE, PP and PVC can be made from renewable resources, not just non-renewable resources. These are all commodity plastics that are mass-produced, low-cost, and not critical to performance for packaging and technical applications. Another sub-group of this bio-based and non-biodegradable plastics includes such as bio-based PA, PTT, PBT. These are mostly for technical, automotive applications (What are bioplastics? 2018).
- *Bio-based and biodegradable group*: includes starch blends, PLA, and PHA. These are very much new in the plastics industry and have been applied for short-lived products for example packaging. This group of bioplastics has been

developed quickly and has the potential to reform the whole plastics industry in the future (What are bioplastics? 2018).

- *Biodegradable and fossil-based group* (such as PBAT and PCL): are relatively small and used in the combination of other bioplastics or starch for specific purposes such as to improve performance and mechanical properties. A bio-based version is already developed and ready to exploit soon (What are bioplastics? 2018).

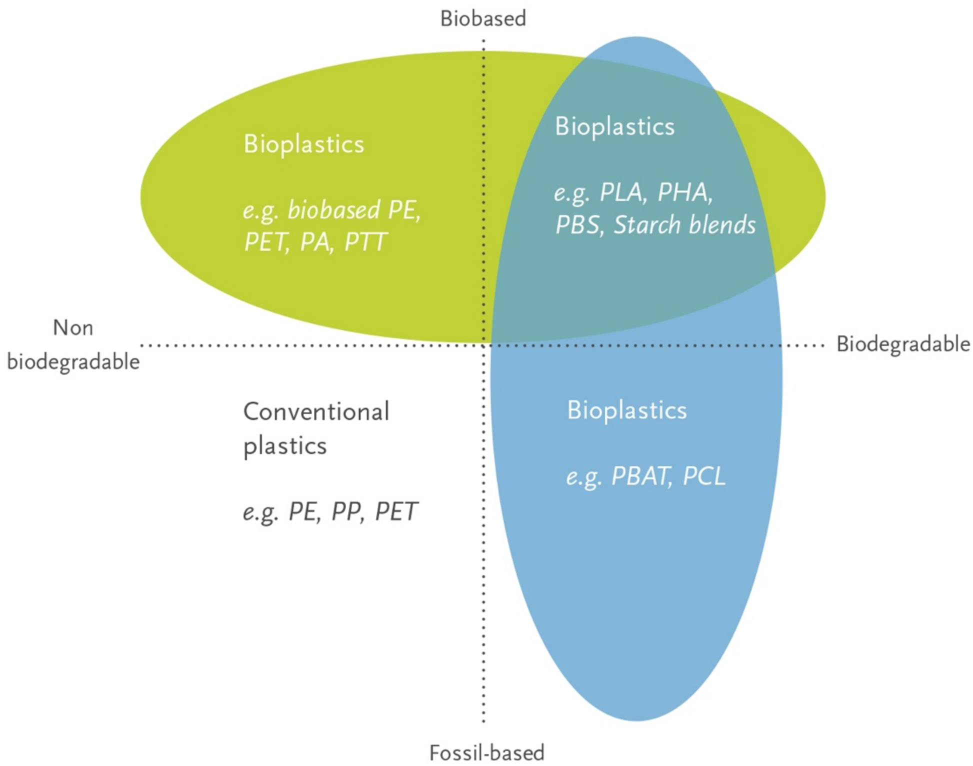


Figure 23. Material coordinate system of bioplastics (Website of European Bioplastics 2020)

Labeling standard

There is confusion in the international market where bioplastics are labeled differently since the standardization processes happened in various places. Here are some of many internationally used labels. These labels are derived from various certification schemes and based on the European and US standards e.g. Belgian certifier TUV Austria (Vincotte), German certifier DIN CERTO, and the United States Department of Agriculture (Website of European Bioplastics 2020).

Bio-based plastics

Bioplastics with bio-based content must specify the numeric percentage value or the typical unit of bio-based content measurement.

Table 1. Labelling bioplastics (Environmental Communication… 2017, 20)

between 20 and 40% biobased; between 40 and 60% biobased; between 60 and 80% biobased; more than 80% biobased	OK biobased with unit of measurement (star sign)
BIOBASED 20 - 50 % DIN Geprüft; BIOBASED 50 - 85 % DIN Geprüft; BIOBASED > 85 % DIN Geprüft	DIN CERTO bio-based certification (with percentage of bio-based content)
biobased %	NEN bio-based content (The Netherlands Standardization Institute-NEN)
USDA CERTIFIED BIOBASED PRODUCT PRODUCT 52%	BioPreferred label with percentage of bio-based content (The United States Department of Agriculture)

Biodegradable/compostable plastics

Labels for biodegradable/compostable plastics should provide further information e.g. timeframe, level of biodegradation, surrounding environments to activate this process of biodegradation or composting.

Table 2. Labelling bioplastics (Environmental Communication… 2017, 20-23)

	OK compost Home		DIN-Geprüft Industrial compostable
	OK compost Water		DIN-Geprüft Home biodegradable
	OK compost Soil		DIN-Geprüft Soil biodegradable
	OK compost Marine		Seedling industrial compostability label (European Bioplastics trademark owner)
	OK compost Industrial (compostable in industrial conditions)		

Applications

Nowadays, bioplastics can be found everywhere as a part of daily life. Bioplastics contribute their role in following market segments just as non-renewable plastics:

- Packaging
- Food-services
- Agriculture and horticulture

- Consumer electronics
- Automotive
- Consumer goods and household appliances

Packaging is the biggest segment of the whole bioplastics industry. Compared to traditional plastics, bioplastics in packaging are green alternatives with similar properties that ensure longer shelf life, the same durability, better preservation of food products, etc. Biodegradable plastics are mostly applied in packaging including flexible packaging and rigid packaging. Flexible packaging can be found in food packaging while rigid packaging can be found mostly on consumer goods and household appliances such as cosmetic packaging, beverage bottle (Website of European Bioplastics 2020).

Single-use applications of bioplastics in food and catering services are essential in the modern world. This is one of many solutions for the single-use sector which aims at sustainable use of single-use plastics that can be either compostable or renewable (Website of European Bioplastics 2020).

Agriculture and horticulture have increasingly utilized biodegradable plastics to reduce the ecological footprint. Biodegradable mulching film for crop production is the most important application of bioplastics in these sectors. Other uses of biodegradable plastics are biodegradable pot plants, wrapping films, etc. Applications from (partly) bio-based durable bioplastics are mostly common in electrical appliances and automobile parts (Website of European Bioplastics 2020).

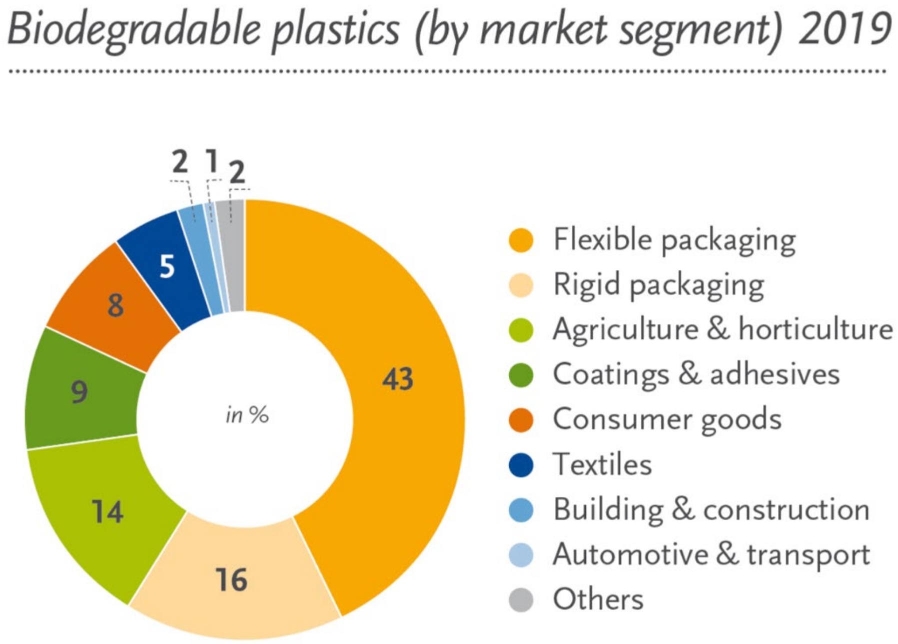


Figure 24. Biodegradable plastics by market segment 2019(Website of European Bioplastics 2020)

8.2 Bioplastics' Pros and Cons

Bioplastics are solutions for several environmental problems. Using renewable biomass to produce bioplastics means we will be less depend on fossil resources. This relates to the greenhouse gas emission from the production as well. Plus, bioplastics improve resource efficiency by for example the cascading use of biomass or the closed-loop production system (Website of European Bioplastics 2020).

Bioplastics help to solve the food waste problem. Currently, there are few bioplastics inventions such as MarinaTex bioplastics from fish scale and red algae utilizing waste streams instead of virgin natural materials to make eco-friendly alternatives to conventional plastics (Website of MarinaTex 2020). When it comes to food services, Single-use plastics waste is one of many issues that bioplastics could be a solution to reduce plastics waste. The food that stuck inside single-use plastics such as takeaway containers, sandwich packaging with ideal composting conditions can be composted together. This reduces the amount of single-use plastics waste as well as methane emission from rotten food in landfills or incineration. The character of being biodegradable makes the process of waste management also becomes less time-consuming and more efficient. The bioplastics waste e.g. home compostable bioplastics can be recycled locally without further necessary transportation (Oakes, 2019).

Bioplastics create new marketing strategies. As for customers who are aware of the damaging impacts of conventional plastics, the trend of preferring eco-friendly products has been growing quickly in recent years. Bioplastics have become more welcoming as substitutes for petroleum-based plastics. The majority of consumer goods and household appliances are made from plastics. Bioplastics are not only better for the environment but also impact customer behavior (MarketLine 2019).

Alongside positive effects emerging from bioplastics, the likelihood of several drawbacks is possible. Only a small fraction of bioplastics is home biodegradable or compostable. The rest then needs to be treated in certain ways usually with industrial composting conditions. Household level of composting bioplastics and categorizing bioplastics is currently not established yet, which might be necessary for the near future. The recycling process is commonly complicated. This comes from the categorizing step of bioplastics. It is usually hard to recycle even for bioplastics if they are not categorized carefully. The extent of being contaminated also affects the recycling of bioplastics. In this case, bioplastics will end up in landfills or somewhere on earth just like conventional plastics and have the same level of impact. The development of appropriate waste management and infrastructure is thus essential to deal with the bioplastics recycling problem (Oakes, 2019).

The fact that bioplastics may solve some of the environmental problems, ocean pollution or plastics crisis is yet not among them. There is something between 4 to 12 million tons of plastics waste is discarded into the oceans every year (Amos, 2020). These plastics take hundreds of years to break down into smaller pieces that pollute and endanger the marine ecosystem. In the meantime, only about 1% of more than 300 million tons of plastics produced annually are bioplastics (Website of European Bioplastics 2020). It will take a long time to replace conventional plastics by biodegradable plastics or figure out better solutions for the battle with plastics.

Eventually, bioplastics give hope for us to solve plastics crisis but it will be so far away with bioplastics solely.

The allocation of agriculture production such as corn for bioplastics production may conflict with food production. Food scarcity is one of many major problems in the modern world where there are more than 800 million people do not have enough to eat (Website of World Food Programme 2020). This allocation will somehow pressure the world food security although the estimation of land use for bioplastics is only a tiny fraction of the global agricultural area at the moment. This might link to agriculture practice as well since a good agriculture practice will increase both productivity and resource efficiency (Website of European Bioplastics 2020).

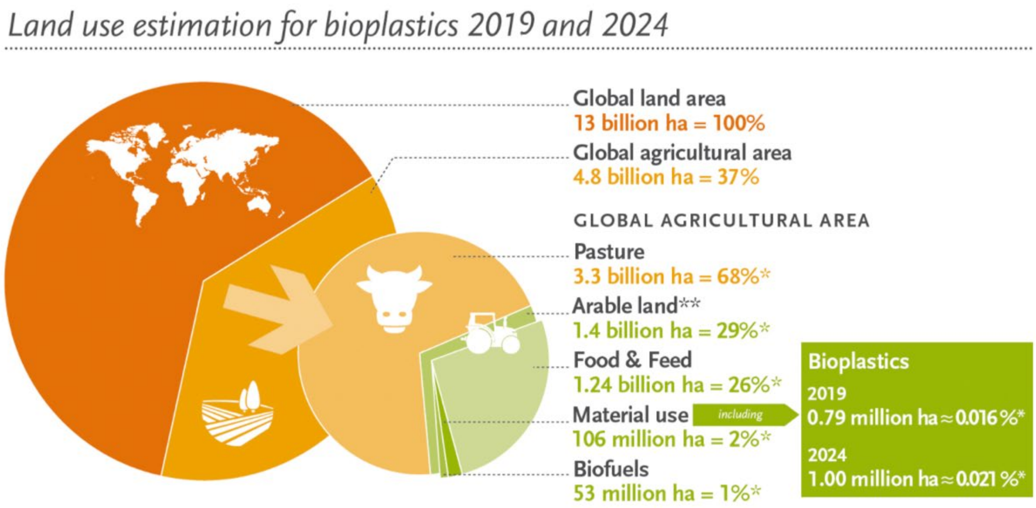


Figure 25. Land use estimation for bioplastics 2019 and 2024 (Website of European Bioplastics 2020)

Bioplastics are a whole family of materials with differing characters, which means not all of the bioplastics are recyclable. Those unrecyclable then have the same impacts as their counterparts if they escape to the environment (Gibbens, 2018). The confusion from the bioplastics labeling system does not work as it is meant to be. This might cause the misconception that whatever labeled bioplastics are biodegradable. And the further drawback is improperly categorized which causes difficulty in the recycling process (Oakes, 2019).

8.3 Bioplastics and market outlook

Since its invention, plastics show up everywhere. We cannot deny the benefits plastics bring to our society such as lightweight, durability, flexibility, and versatility. However, the wide-range applications make us progressively depend on plastics. Until today, we have not figured out how to deal with plastics. Consequently, we trash our planet with nearly 7 billion tons of plastics since its first mass production (Parker & Olson 2018). The rise of bioplastics as green alternatives has caught our attention in recent years. Whether bioplastics has helped us deal with plastics crisis or need to be tested out in couple more years, the introduction of bioplastics into the market has certain impacts on the customer perception and the reaction of businesses towards these eco-friendly alternatives (MarketLine 2019).

Consumers are now more committed to environmental issues. Researchers have shown that the public awareness of plastics impact has been growing. There must be a change to deal with this plastics affair. The novel bioplastics show its potential that can contribute to the plastics crisis and are widely accepted by consumers. The majority of consumers are willing to pay extra for environmentally friendly packaging and reduce plastics packaging. Consumers now have the power to push the packaging industry to adopt better practices for packaging solutions and then enforce policy-makers to take part in this combat (Waldersee, 2019). Bioplastics though have positive effects on consumer behavior, it can be concluded that there is still confusion in directives, labeling standards, certificates relating to the quality of compostability, biodegradability. Besides, waste management mistrust, lack of government support, ignorance on the topic turns this bioplastics topic into a more complex phenomenon (Burrows, 2018).

From a business point of view, the idea of adopting bioplastics might raise consumer awareness of the environment gradually and set a new trend in the market where products with natural origin would be more valued. The nature of eco-friendly products is to encourage the sustainability concept that should be promoted by the government and carried out by businesses (MarketLine 2019). Currently, bioplastics have not completely proved to be the best alternatives to traditional plastics or any better (Gibbens, 2018). Additionally, the trouble with bioplastics labelling and certificate causes the misunderstanding of these bio-products for not only consumers but also brands and designers. The most suited practice for businesses is to avoid false environmental claims and greenwashing when they themselves are not certain about what they provide for their consumers (Burrows, 2018). It turns out that research and development of bioplastics needs more investments. The support from the whole society is also a critical factor for the development of bioplastics with their genuinely biodegradable characteristic that would completely replace non-renewable plastics.

8.4 Why do bioplastics become a trend nowadays?

From these findings, it can be concluded that bioplastics have so far had an impact on consumer awareness in terms of the environment. Climate change, plastics crisis along with other major global challenges force human gradually acknowledge their impacts to the globe and adopt a better lifestyle that might contribute to the mitigation of these crises. Bioplastics inherit a set of characteristics that are more advanced such as being bio-based and biodegradable than their counterparts. The development of a better plastic material that is from non-renewable resources and sustainable is very much in line with the bioeconomy concept. The rise of bioplastics, at the same time, also comes from the marketing strategies. The claims of being bio-based, biodegradable, or compostable has critically shifted consumer awareness to greener options and supported brands with environmentally friendly products. However, the introduction of bioplastics into the market has not been very effective yet since both consumer and provider do not thoroughly understand what is bioplastic. Consequently, bioplastics came into the market as such a vague and ambiguous term. In other words, the recent popularity of bioplastics has both advantages and disadvantages. In the end, the idea of bioplastics is great for the environment and help to cope with plastics crisis but still need more works to ensure its genuineness as being bio-based and 100% biodegradable. Plus, there should be a clear guideline for labelling standard and certificates of bioplastics. These guidelines then must be easily accessed by the population. The investment in appropriate infrastructure is again crucial to effectively recycle used bioplastics.

9 CONCLUSION AND SUMMARY

Bioeconomy has been a trending topic in recent years for many reasons. Among those reasons, the global concern over environmental issues is probably the most significant. Unlike our current economy, the bio-based economy aims to utilize renewable resources to run the society with the sustainability concept as its core. In the light of it, it is essential to educate people especially academic readers about the topic. This will enhance the knowledge of a new phenomenon like bioeconomy. At the same time, readers will be more aware of our impacts on the planet wellbeing. This might encourage people to think innovatively and sustainably, which leave less environmental footprints and promote sustainable development. The main goal of this thesis is to build a handbook of bioeconomy fundamentals is much of these expectations.

The intention of doing a secondary research on bioplastics assists not only the readers but also himself in acknowledging multiple sides of a controversial bio-based product. Bioplastics topic has well served as a typical example that helps readers to get hold of the background of biobased plastics as well as its potential in the current market. When it comes to reliability and validity, the fact that this secondary research is based on various secondary sources on the internet might affect the research quality. However, by comparing different data from trustworthy sources, the author had the ability to generalize informative and reliable findings on the bioplastics topic. Throughout this secondary research, all the findings are closely based upon recently published articles and researches on European Bioplastics website, BBC website, The Guardian website, National Geographic website, etc. Plus, the author also made use information from YouGov website, MarketLine database, Website of MarinaTex (for an example). Although the risk of being unreliable internet sources, the author found that these websites provided very much consistent data and shared the same view on bioplastics. The extent of being biased or untrustworthy data, thus, are somehow eliminated. In other words, this research reached its reliability by consistent findings and transparent research process. Additionally, the data on those websites had spoken for itself and are also the answer to the research problem in this secondary study that the author would like to understand and deliver to his readers. The findings of bioplastics interestingly assisted the narration of the bioeconomy concept and gave a review of the bioplastics popularity within the bioeconomy context. This indicates that the secondary research has ensured its validity by means of archival and documentary research approach. These research findings helped the author in answering the main research problem. It is also found that these research findings supported each other and revealed the answer for the popularity of bioplastics clearly. Moreover, they could be generalized in other research settings within the context such as green packaging concern, consumer behavior towards single-use plastics and bio-based plastics. In short, by the examination of bioplastics only, we have acknowledged the idea of bioeconomy is to firstly deal with major global challenges, and support the sustainability concept towards the sustainable development of our society.

It can be said that the author has reached the thesis outcome that is to build a handbook of the fundamentals of bioeconomy to academic readers. The author has solved many research questions in this thesis. This accomplishment is also the quest for answering research problems and research objectives as well as reaching the thesis purpose. Essential parts of this thesis will be used for making the handbook. The topic of bioeconomy was very much unfamiliar with the author at the outset of this study. Throughout the writing process, there are several parts that are difficult to understand and rewrite as the extent of technical and scientific language. This is also one point that the author is not satisfied with since he believes it should be better if the handbook could be written in less technical language that everyone would interest in reading. Otherwise, academic readers might find the handbook informative and helpful for educational purposes. Additionally, the secondary research might not show its best to evaluate the value of bioplastics. The implementation of a secondary research is another limit in this thesis. A primary research with a mixed methodology might bring more valuable insights and up-to-date information. Regarding ideas for further study, the author believes that the topic of people’s awareness of not only bioplastics but also bio-based products would be interesting to know. Plus, the author also supports business ideas promoting sustainable goals such as providing eco-friendly products, sharing knowledge of low-impact lifestyles.

All in all, the biggest achievement during writing this thesis that the author has educated himself with the bioeconomy concept as well as bioplastics. The thesis process has lasted over a year; however, the author is positive with the research result and his effort on finalizing the thesis. The writing thesis process has improved many skills for the author. Writing, critical thinking, presenting, being consistent are many of them. Moreover, the author also taught himself to use new tools such as InDesign for creating the handbook, which might be valuable in his future career. Writing this thesis encouraged the author to touch on complicated aspects. In addition, self-reflection is an important part of writing this thesis. The author is personally pleased with the thesis and the outcome. With the handbook, the author hopes his readers will find this topic fascinating and come up with great ideas that would contribute to the sustainable development goals.

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